sPHENIX Project Status Report – February 2021

HOST LABORATORY: BROOKHAVEN NATIONAL LABORATORY

FEDERAL PROGRAM MANAGER: ELIZABETH BARTOSZ

BHSO POINT OF CONTACT: ROBERT CARADONNA

CONTRACTOR PROJECT DIRECTOR: EDWARD O'BRIEN

1. **SCORECARD AS OF February 28, 2021**

Current PD:	**2/3**	Date of Current CD/PD approval		September 2019	
Next PD:	**4**	Forecast approval:	**1QFY23**	Baseline:	**1QFY23**
% Complete:	**64.2%**	Planned:		**79.9%**	
ETC:	**$8.93M**	TPC or Cost Range:		**$27.0M**	
Contingency:	**24.0%** on ETC	Float to PD-4 in months:		**10.75**	
Cumulative CPI:	**1.02**	Cumulative SPI:		**0.80**	

2. **NEAR TERM MILESTONES**

The sPHENIX Project team will continue the monthly EVMS process, Change Control, and updating of the ETC. We will continue to place orders for detector components approved at PD-3. We are continuing to implement a plan to mitigate COVID-19 related delays and have hired additional technical and engineering labor at both BNL and universities to maintain the project schedule. We expect that the schedule delays will reduce after February as the COVID peak continues to decrease in the US, delayed vendor deliveries start to arrive at BNL and our labor increases begin to mitigate the effects the pandemic is having on the schedule. We expect the SPI to slowly improve over the next few months due to these factors. The project cost performance remains excellent. We will continue to hold Final Design Reviews and Production Readiness Reviews as detector components move from prototyping and design to production.

The TPC field cage pieces will begin assembly into the final full unit. The aluminum stripes will be evaporated onto the TPC central membrane petals. Full production of 700 TPC FEE boards will be ordered pending a successful test preproduction round electronics from Edmond Marks.

Production of EMCal blocks for Sectors 13-64 will continue at UIUC. The current rate of block production is close to the level required to complete all of the blocks by the end of 2021 but needs to increase slightly to reach this goal. We expect an additional full time machinist to be hired soon at UIUC. EMCal module production and sector assembly will continue at BNL. We expect that a temporary shortage in EMCal sector preamps will be resolved in April.

ISU and Rutgers will continue to coordinate with the IHCal frame vendor to ensure good communication and adherence to the production schedule. First delivery of 25% of the IHCal sectors is expected over the next 3 months. We will complete the assembly and initial testing of the OHCal sectors and begin burn-in tests of the on-detector electronics.

Work on the Calorimeter Electronics over the next 3 months will be focused on the continued testing of assembled EMCal and HCal sectors, and design and construction of racks for on-detector electronics. This work includes the completion of testing of EMCal SiPM boards and preamps, fab of HCal power rack, build of the first Cal Digitizer rack with a fully operational crate, fab of LVPS and cable orders

The DAQ/Trigger group will devote most of the next month's work to the preparations for the sPHENIX Software and Computing review, where we will finish the demonstration of the proper alignment of data taken from different readout systems. We will then resume the work of implementing the readout of the Global Level 1 (GL1) data using our standard hardware that had to wait for this higher-priority work. We will be holding the design review for the Local-Level 1 system, which will be reported in the March monthly report.

Columbia University collaborators will send all components needed to carryout the full chain test at BNL including three MBD prototype D/S boards, the clock-fan out board, the clockmaster, and the crates. Columbia University personnel will proceed to work on the procurement of the production MBD electronics.

3. **STATUS HIGHLIGHTS**

Production components for the sPHENIX detector continue to arrive. Most of the recent project activities are associated with production of final detector components. Remaining R&D is nearly complete and is limited to electronics and calibration components for the detector.

The early completion date for sPHENIX slipped one week later during February. It is now the first week of February 2022. Ten months and three weeks of schedule contingency to the PD-4 date remains. The project cost performance remains excellent. EVMS processing was completed for February. Cobra and P6 monthly reports uploaded to IPD. The variance reports were approved. A PCR was approved in February to add in contract numbers for the IHCal Support Rings. The project is 64.2% complete in February with a 24% contingency on the ETC. The project is 84.4% costed and committed.

The third and fourth major shipments of TPC GEM foils arrived on time from CERN and are in the hands of the factories putting us past the half-way point in GEM delivery. The production R1 pad plane has shipped but not yet arrived at SBU. Magnetic field tests on the TPC FEE optical components and the line laser were completed with all systems passing 100%. This test is the final step required to place full orders for the line lasers. The order of the cooling blocks for the TPC was placed. The sub atmospheric recirculator for TPC on-detector cooling was ordered. Delivery of the pre-production FEE cards is complete and performance verification is underway. The TPC Fee preproduction cards have passed all tests to date. An evaluation of competing slow-services options (New Jack cards vs. extra Felix cards) is completed in favor of the Jack card solution.

As of the February close, 25% of the EMCal blocks for sectors 13-64 had been produced and 21.4% of the blocks had been shipped to BNL. The rejection rate for blocks currently being produced is ~ 2.7%. In addition, 72% of the fiber assemblies for Sectors 13-64 have now been filled. The peak block production rate reached ~ 70 blocks per week while the 4 week moving average was 57 blocks per week. The goal is 66 blocks/week, which UIUC believes that they can obtain with the addition of another machinist in the UIUC block factory. UIUC is in the process of hiring this person. All of the modules for Sectors 1-17 have been completed and work is continuing on the modules for Sectors 18. Eleven sectors have been completed and tested. Assembly is proceeding on Sectors 12

and 13 and blocks are being glued into Sectors 14-17. BNL received a shipment of 60 preamps, which, after assembly and testing, will be enough to complete up to Sector 15.

ISU has contracted with a vendor to produce the IHCAL sectors. Raw material has been ordered and a delivery schedule has been provided by the vendor has been integrated into P6. Factory operations at BNL are continuing with technician labor and collaborator support from collaborating institutions (Baruch, UC Boulder, Rutgers, Lehigh, Ohio, and ISU). A total of 26/32 sectors have been completed as of the writing of this report, and all parts are on hand to complete the remaining 6 in the next few week. Preparations are being made to burn-in the sectors in storage, starting in late March when a burn-in test rack should be available. The full shipment of high-strength endplates, splice plates, and pucks and pins for oHCAL assembly has been delivered to BNL.

Testing of all the on-detector OHCal electronics was completed in February and the electronics was delivered to the HCal group for installation. There was a delivery of 25% of the bias supply modules for the EMCal and HCal in February with ship date of the remaining supplies scheduled for March of 2021. The vendor for the LV bulk supplies has informed us that they expect to start shipping in April 2021. The procurement documentation for the full digitizer system parts was submitted to the Columbia University purchasing department and purchase orders are being processed.

We performed a large scale test for the buffer boxes in which we have written the equivalent of 10 hours worth of sPHENIX data taking (500 million events), which fills up about 45% of the available disk space. This test also exercised our proposed data writing protocol, SFS, which performed about 30% faster than the NFS server protocol did. We also performed tests of offline event building that was shown to work.

A FDR was held for the MBD electronics on Feb. 8. The only major comment from the review was that we should do a full chain test with the BBC, actual cables we will use to send the signals, and the new electronics. An anomalous timing result from an earlier bench test of the prototype MBD electronics has been resolved. We achieved a 30-40 ps timing resolution in all tests.

WBS 1.1 Project Management (L2 Manager: Irina Sourikova)

Current Status

- SPI is 0.80, CPI is 1.02.

Highlights:

- Schedule contingency reduced by 7 days. Just under 11 months of schedule contingency remains.
- PCR for IHCal Support Rings placed contract, positive $44K contingency impact.
- MBD Electronics Final Design Review complete.
- EVMS processing complete.
- Cobra and P6 monthly reports uploaded to IPD.
- Variance reports approved.

Plans for the next 2-3 month:

- Continue monthly EVMS process and Change Control.

- Implement corrective actions to improve schedule performance.

Issues:

- None

WBS 1.2 Time Projection Chamber (L2 Manager: Tom Hemmick, SBU)

Current Status:

GEM foils from the third and fourth major shipments arrived from CERN on time and are in the hands of the factories putting us past the halfway point in GEM delivery.

The R1 pad plane has shipped but not yet arrive at SBU.

Magnetic field tests on the FEE and the line laser were completed with all systems passing 100%. This test is the final step required to place full orders for the line lasers. A design change for the motor controls was warranted by marginal performance of test samples from the DTI Company. The redesign using Nanomotion motors is completed. These motors provide a force on an externally engineered wheel that enables the engineer to build in a significantly higher safety factor. Orders for the final design motors are ready to be placed. TracePro simulations of the quartz bars transporting the line lasers into the TPC volume have quantitatively evaluated light losses due to know-achievable corner quality and mounting hardware dead spots. Both effects are found to be well under light loss tolerance specs, enabling the purchase of quartz bars to be readied.

The order of the cooling blocks for the TPC was placed. The sub atmospheric recirculator for TPC on-detector cooling was ordered. The order for on-TPC mounting hardware for the cooling (partially custom and partially off-the-shelf) is quoted and ready to be placed.

Delivery of the pre-production FEE cards is accomplished and verification has passed all tests to date. An evaluation of competing slow-services options (New Jack cards vs. extra Felix cards) is completed in favor of the Jack card solution. The latter solution requires an optical sorting box for which a suitable vendor has been identified.

Production proceeds apace on the TPC assembly cart in the SBU shops and also the external company Strecks. Initial issues with material quality at Strecks were resolved favorably and generated no additional delay.

Work Anticipated for the next 2-3 Months:

The Al stripes will be evaporated onto the central membrane petals. The field cage pieces will begin assembly into the final full unit. Full production FEE will be ordered pending a successful preproduction round from Edmond Marks.

Issues

Several GEMs at each factory were identified as having superficial flaws. Although the rate of such flaws is still better than assumed on our schedule, we have nonetheless sent the substandard items back to CERN for rework and to minimize similar issues in future production.

COVID Impacts: The SBU team was idled for 10 days due to a false positive COVID test of one of our central team members and contract tracing for the remainder of the team. The team plans to work weekends in March to restore the schedule.

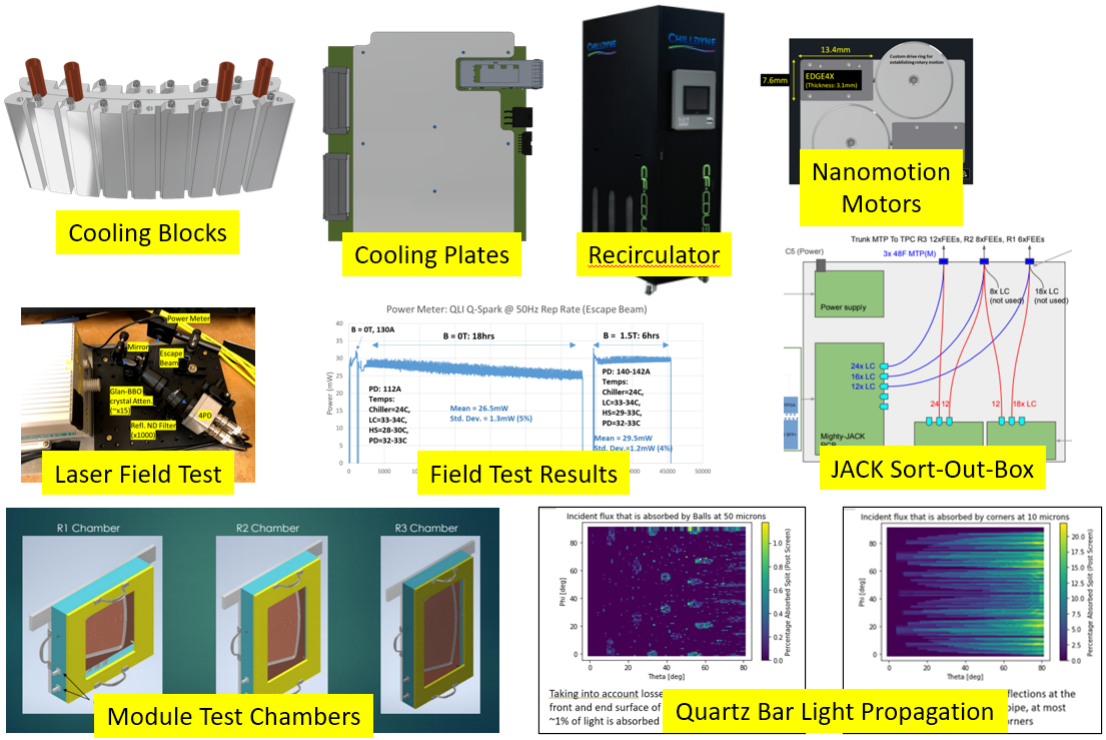


Figure 1: Clockwise from upper left: 3-D model of cooling blocks and cooling plates; recirculator for TPC Fee cooling; nanomotors for laser position control; fiber mapping for TPC electronics "sort out box"; quartz fiber performance specs for laser system, 3-D model of R1, R2, R3 GEM modules; results from laser test in 1.4 T B-field.

WBS 1.3 Electromagnetic Calorimeter (L2 Manager: Craig Woody, BNL)

Current Status:

Figure 2 shows the status of block production at UIUC for Sectors 13-64 as of February 26th. As of that time, 25% of the blocks for sectors 13-64 had been produced and 21.4% of the blocks had been shipped to BNL. The rejection rate for blocks currently being produced is ~ 2.7%. In addition, 72% of the fiber assemblies for Sectors 13-64 have now been filled.

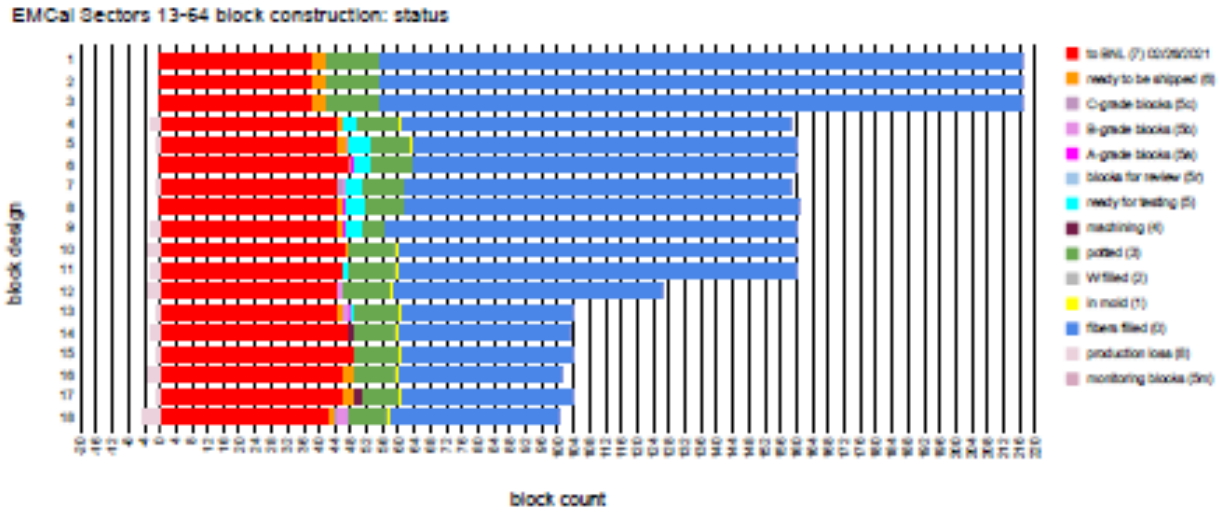


Figure 2: Progress on block production for Sectors 13-64 at UIUC as of February 26st.

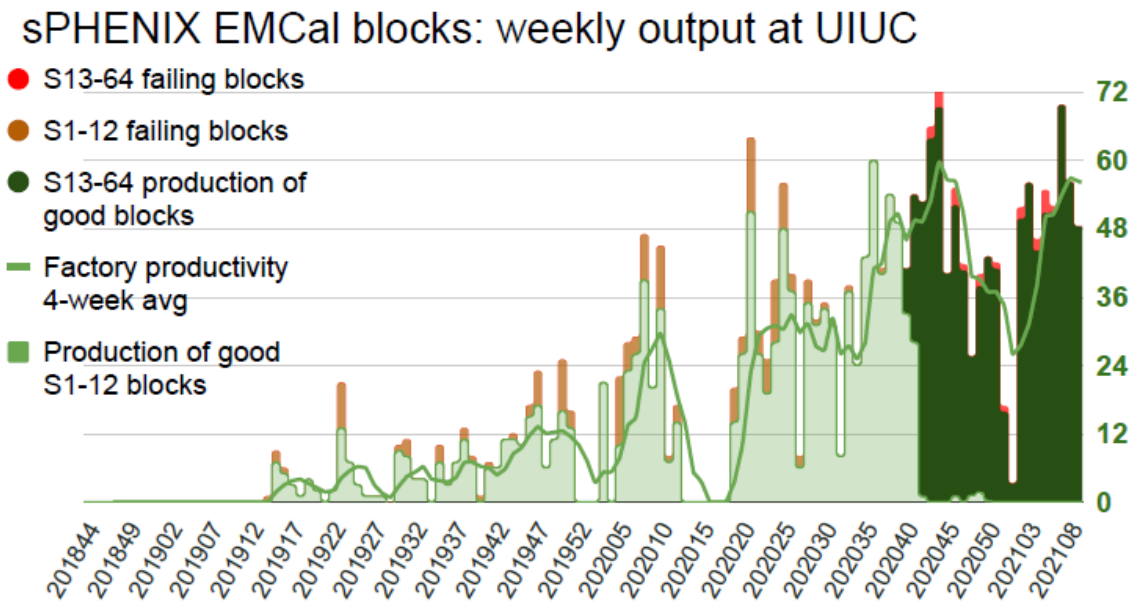


Figure 3: Weekly rate of block production at UIUC (moving average over 4 weeks).

Figure 3 shows the weekly rate of block production at UIUC. The peak rate reached ~ 70 blocks per week while the 4 week moving average was 57 blocks per week. In order to complete the production of all the remaining blocks by the end of 2021, we need to achieve an average rate of 66 blocks per week. The current rate is limited due to a lack of personnel needed to machine the blocks. UIUC is planning to hire an additional machinist to help with this work.

Block production also continued at Fudan, although the activities there were slowed down due to the Chinese New Year. However, they plan to add two additional full time employees and send ~ 150 blocks to be machined in early March. These blocks would then be shipped to BNL in late March.

Work on module production and sector assembly continued at BNL. Figure 4 shows the status of the various stages of module production as of Feb 26th. All of the modules for Sectors 1-17 have been completed and work is continuing on the modules for Sectors 18. We now have enough light guides to complete modules for up to Sector 26, and delivery of more light guides is continuing on a regular basis. Figure 4 shows some of the light guide assemblies being prepared for installation on the modules.

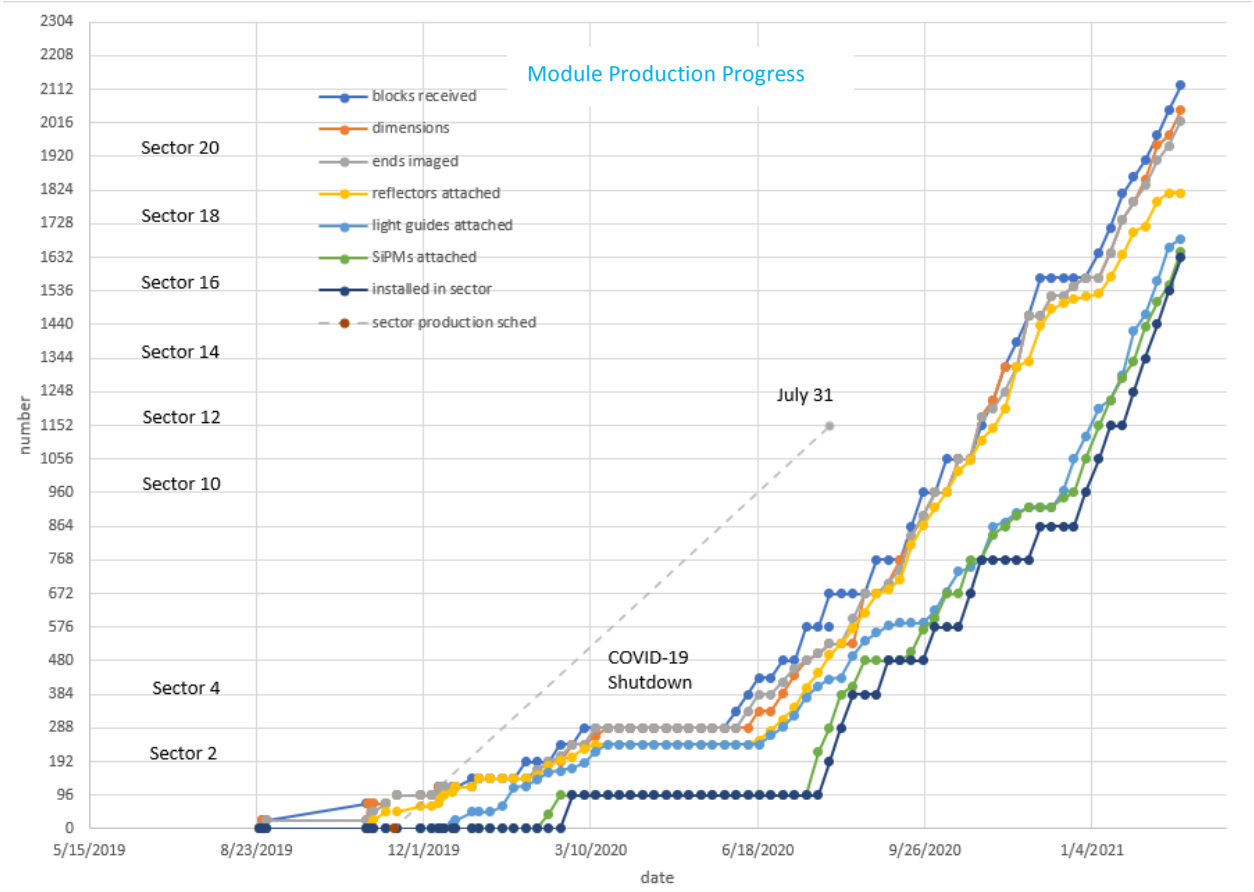


Figure 4: Status of module production at BNL as of Feb. 26th.

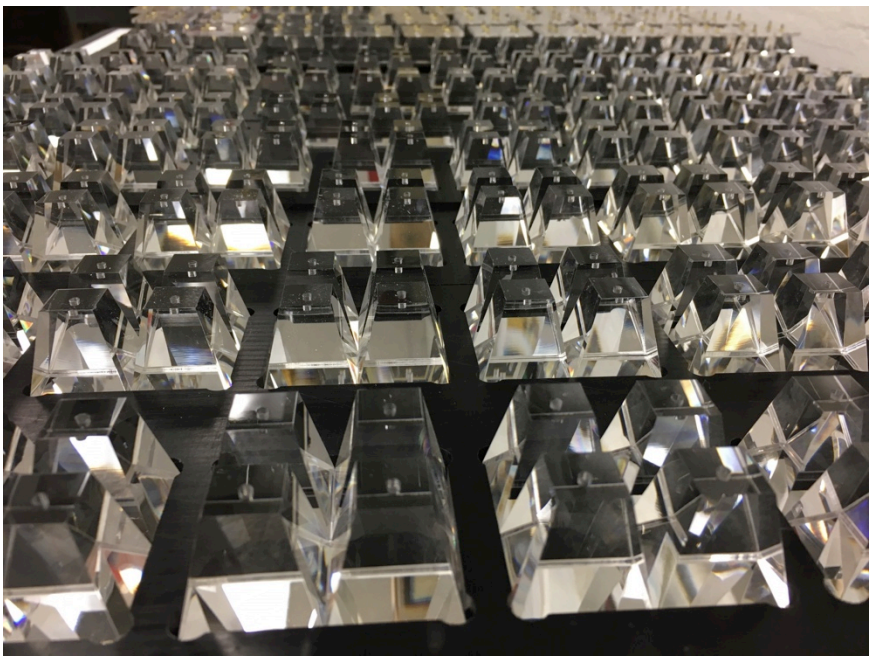


Figure 5: Light guide assemblies being prepared for installation onto modules.

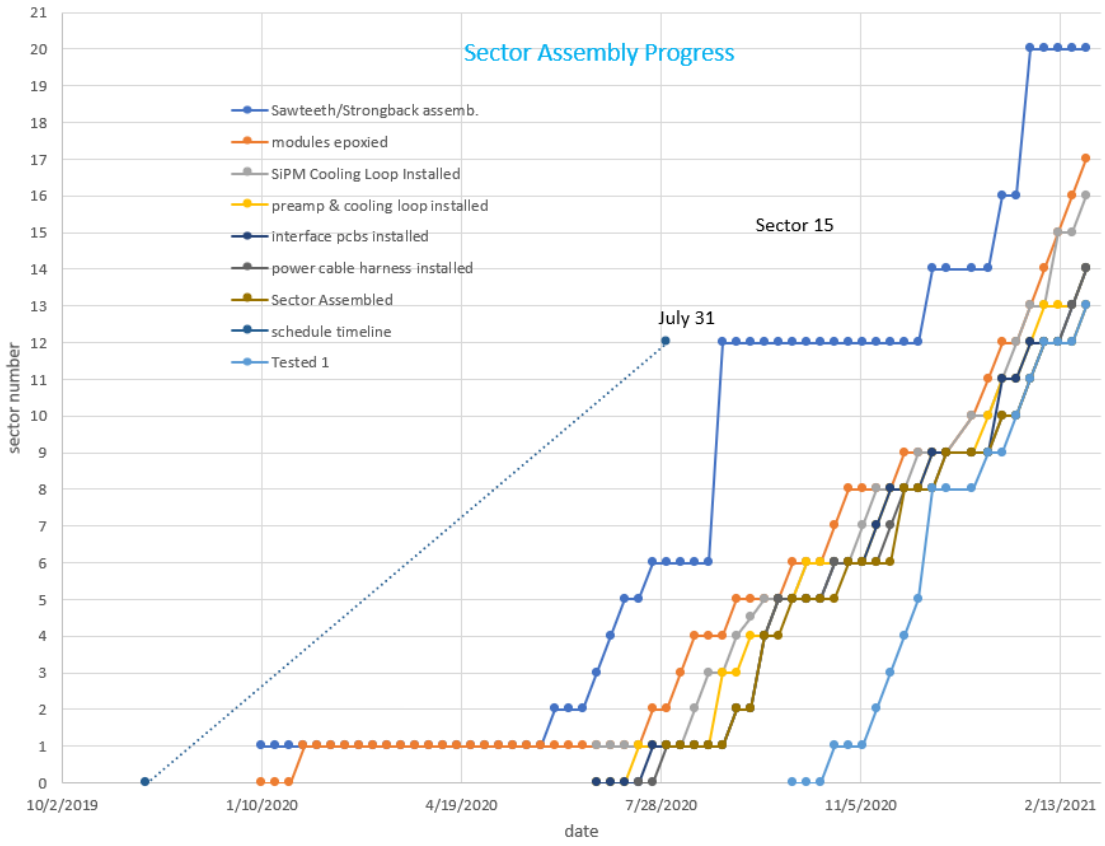


Figure 6: Status of sector assembly at BNL as of Feb 26th.

Figure 6 shows the status of sector assembly. Eleven sectors have been completed and tested. Assembly is proceeding on Sectors 12 and 13 and blocks are being glued into Sectors 14-17. We have received enough cooling loops to complete up to Sector 24 and enough sawteeth to complete up to Sector 20. More sawteeth (enough for up to Sector 38) are ready at the Stony Brook Machine Shop. We also received a shipment of 60 preamps, which, after assembly and testing, will be enough to complete up to Sector 15.

Work For the Next 2-3 Months:

Production of blocks for Sectors 13-64 will continue at UIUC. The current rate of block production is close to the level required to complete all of the blocks by the end of 2021 but needs to increase slightly to reach this goal. Once the additional full time machinist is hired, we expect that this will be achieved. Production of the high rapidity blocks for Sectors 13-64 will also continue at Fudan. We expect that the rate of block production will increase and reach the level of 24 blocks per week that is required to keep up with the production of blocks at UIUC and allow full sector production to continue at BNL.

Module production and sector assembly will continue at BNL. There are sufficient parts to complete up to Sector 15, but after that we will not have enough preamps to continue with completing and testing full sectors. It is expected that additional preamps will become available in April. In the meantime, we will assemble sectors up to the point of installing the preamps and then set them aside until additional preamps arrive.

Issues:

We have two main issues of concern:

1. UIUC needs to hire an additional machinist in order to increase their rate of block production up to the level required to finish all the blocks by the end of this year. This is being held up by various administrative problems at UIUC and there are efforts underway to solve this problem at a high level.
2. We will soon be limited in our ability to complete full sectors due to the lack of preamps. This is due to a delivery problem of some critical electronic components and we are expecting that more preamps will become available sometime in April. In the meantime, we will partially complete sectors and set them aside and then complete them after the preamps become available. This will be disruptive to our sector assembly and testing procedure and could cause a delay in our schedule. (**Editors note:** The missing preamp components arrived at the electronics assembly house in mid-March and tested preamps will start to arrive at BNL the first week of April.)

WBS 1.4 Hadronic Calorimeter (L2 Manager: John Lajoie, Iowa State University)

WBS 1.4.1 Inner Hadronic Calorimeter

Current Status:

ISU has contracted with Technical Services, Inc., (TSI) to provide the iHCAL sectors. Raw material has been ordered and a delivery schedule has been provided by the vendor has been integrated into P6. The delivery

schedule has been coordinated with Rutgers to ensure that the parts provided will arrive well in advance of when they are needed for assembly. First article inspection is expected by 5/21/2021 with delivery of the first eight sectors shortly thereafter.

The iHCAL end ring material has been received by the vendor and the material certifications have been approved by the BNL engineers. Machining by the vendor is underway.

Work for the Next 2-3 Months:

ISU and Rutgers will continue to coordinate with IHCal frame vendor TSI to ensure good communication and adherence to the production schedule.

Issues:

The COVID-19 pandemic can potentially have a negative schedule impact on the inner HCAL assembly schedule due to the availability of student labor in summer 2021. It will be critical that iHCAL sector assembly proceed quickly to avoid delays in the sPHENIX installation schedule.

WBS 1.4.2/3/4 Outer Hadronic Calorimeter

Current Status:

Factory operations at BNL are continuing with technician labor and collaborator support from collaborating institutions (Baruch, UC Boulder, Rutgers, Lehigh, Ohio, and ISU). A total of 26 sectors have been completed as of the writing of this report, and all parts are on hand to complete the remaining 6 in the next few week. Preparations are being made to burn-in the sectors in storage, starting in late March when a burn-in test rack should be available. Work is underway to complete analysis of the cosmic ray and LED data and prepare the initial calibration constants for the sPHENIX offline database.

The full shipment of high-strength endplates, splice plates, and pucks and pins for oHCAL assembly has been delivered to BNL. The high-strength endplates have passed QA and been installed on four sectors. The remaining parts are in the middle of the QA process, with initial results looking very good.

Work for the Next 2-3 Months:

Over the next several months work on the outer HCAL will center on completing production sector assemblies in the HCAL factory.

Issues:

None.

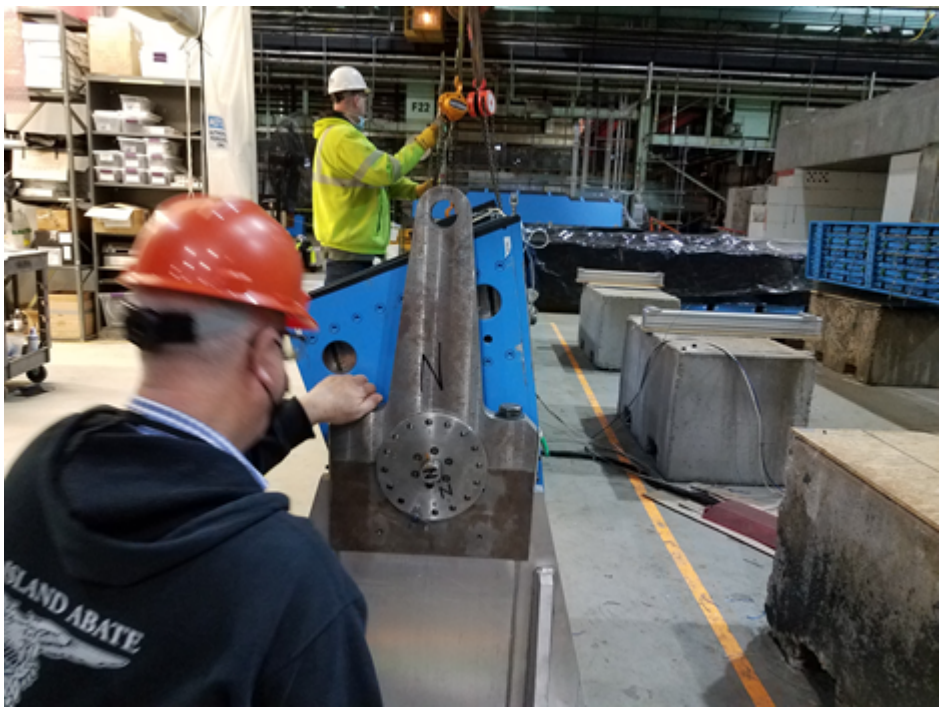


Figure 7: Riggers at the 912 OHCAL factory setting up for a rotation test for cosmics ray calibrations. Cosmic data will be taken at a selection of angles that represent the angles the sectors will be at when fully installed in the sPHENIX barrel, allowing a normalized comparison between all sectors.

WBS 1.5 Calorimeter Electronics (L2 Manager: Eric Mannel, BNL)

Current Status:

Testing of all the on-detector oHCal electronics was completed in February and the electronics was delivered to the HCal group for installation. The assembly of the remaining cable assemblies for the last oHCal modules is on schedule for delivery the first week of March. The vendor assembling the EMCal preamps received an early delivery of parts at the end of January and delivered 60 preamps, which passed final quality assurance testing which was done by a University of Colorado, graduate student stationed full time at BNL. The remaining parts for the full production were received by the vendor at the end of February with the assembly processes scheduled to start the first week of March with partial deliveries expected late March and final delivery in early April.

There was a delivery of 25% of the bias supply modules for the EMCal and HCal in February with ship date of the remaining supplies scheduled for March of 2021. The vendor for the LV bulk supplies has informed us that they expect to start shipping in April 2021, with a detailed delivery schedule to be provided in March of 2021. Procurement documentation for the external cables for the EMCal and HCal is in the process of being prepared with a target date of March for submission to BNL procurement. The EMCal burn in rack was delivered and installed in the High Bay of the BNL Physics Department. Work has started on the assembly of the HCal burn in rack, which will be used to power the HCal once it is installed.

The procurement documentation for the full digitizer system parts was submitted to the Columbia University purchasing department and purchase orders are being processed. The University of Colorado group continues to develop documentation and testing software necessary for the detailed testing of the digitizer boards.

Work for the next 2-3 months:

Work over the next 3 months will be focused on the continued testing of assembled EMCal and HCal sectors and design and construction of racks for on-detector electronics. This work includes:

1. Testing of EMCal SiPM boards and preamps
2. Build the HCal power rack
3. Build the first Digitizer rack with a full crate operational.
4. Place orders for external cables.
5. Production of low voltage systems.

Issues:

- COVID-19 travel and work restrictions will impact the short-term schedule for testing of delivered electronics.

WBS 1.6 DAQ/Trigger (L2 Manager: Martin Purschke, BNL)

Current Status:

The setup of the previously procured data acquisition PCs and the Buffer Box (shown in Fig.8), one of 6 total, has been completed and more systematic performance tests have been done.

Figure 8: A picture of the disk enclosure with 102 14TB disks during setup.

Using the previously established 15 individual instances of readout processes, we changed the previous method of writing the data to the buffer box using the NFS protocol to a different protocol, nick-named “Super Fast Server” (SFS) that has significantly less overhead that a generic NFS server needs to have. For a large-scale test, we have written the equivalent of 10 hours worth of eventual sPHENIX data taking (500 million events), which fills up about 45% of the available disk space. With 1/6 of the resources installed so far, those 10 hours took 60 hours in real time. This tested the performance of the SFS, which performed about 30% faster than the NFS server did.

The data for each data taking “run” were written in 4 groups of 15 files, one per instance of the readout process. The resulting set of 60 data files were designed in a way that they closely mimic what the later event structure will look like, and in a way that they can be combined into a full events using an offline event builder. That offline event builder, a utility called *event_combiner*, takes the 60 files and writes out the fully assembled event files (Fig.9). That is the reason for the choice of 10 hours of data and a disk usage of 45%, so we still had room to write the combined event data files.

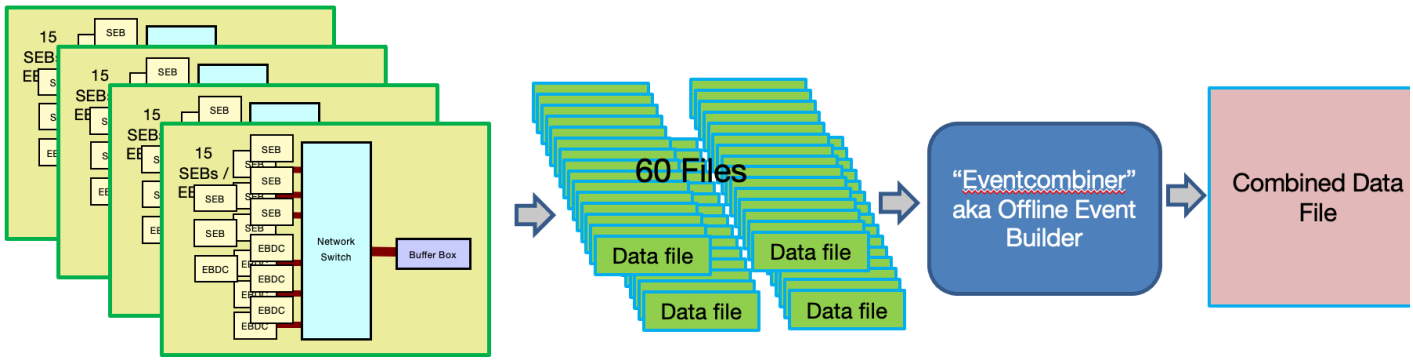


Figure 9: An overview of the large-scale test writing the equivalent of 10 hours worth of sPHENIX data. With 15 available readout instances we wrote 4 groups of 15 files each, and ran the offline event builder to combine them into one "full" data file.

In order to test event building process, the combined data file was read back using our standard analysis framework, *together* with the 60 original files. We then checked that all data were accounted for in the combined data file and identical to the originals (Fig. 10).

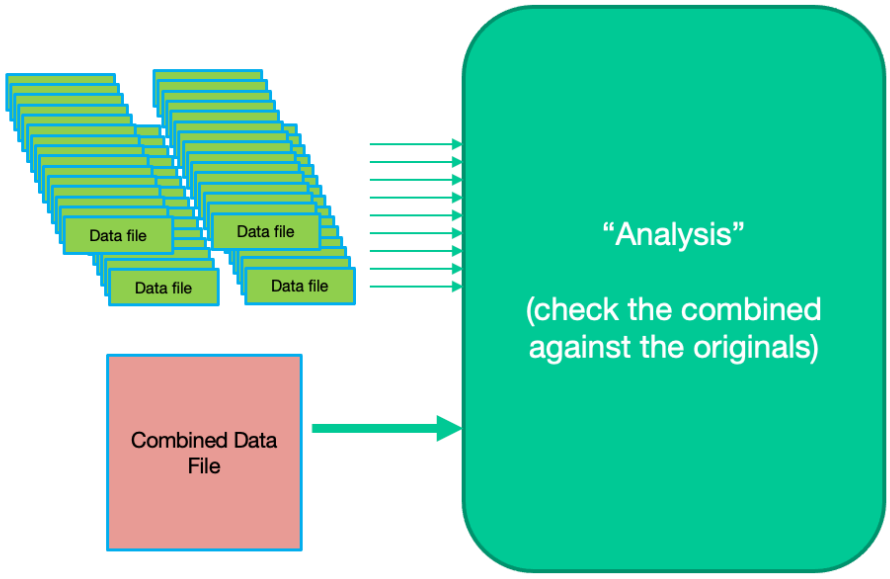


Figure 10: The verification of the offline event builder. The combined data file was read into the standard analysis framework *together* with the 60 original files. The data structures were then checked that they are identical and complete.

This shows that we are able to perform the offline event building, and are able to read back the combined data file, as well as the 60 individual streams. As the strategy for managing the raw data input files for the offline reconstruction evolves, we know that both ways are viable options.

Work for the next 2-3 months:

Most of the next month will be devoted to the preparations for the sPHENIX Software and Computing review, where we will finish the demonstration of the proper alignment of data taken from different readout systems. We will then resume the work of implementing the readout of the Global Level 1 (GL1) data using our standard hardware that had to wait for this higher-priority work.

We are close to holding the design review for the Local-Level 1 system, which will be reported in the March monthly report.

There was no impact due to COVID-19.

Issues:

None

WBS 1.7 Minimum Bias Trigger Detector (L2 Manager: Mickey Chiu, BNL)

Current Status:

We had the final design review for the MBD electronics on Feb. 8. The only major comment from the review was that we should do a full chain test with the BBC, actual cables we will use to send the signals, and the new electronics. The signals can be generated with a laser or cosmic rays. Also, after the review, a Columbia Univ/Nevis Labs scientist re-did his multi-board tests, and a BNL scientist analyzed this data. This time, the anomaly with the somewhat poorer resolution for the delayed path disappeared, and we are achieving 30-40 ps resolution in all tests. The suspicion is that there was a loose or swapped cable in his earlier tests.

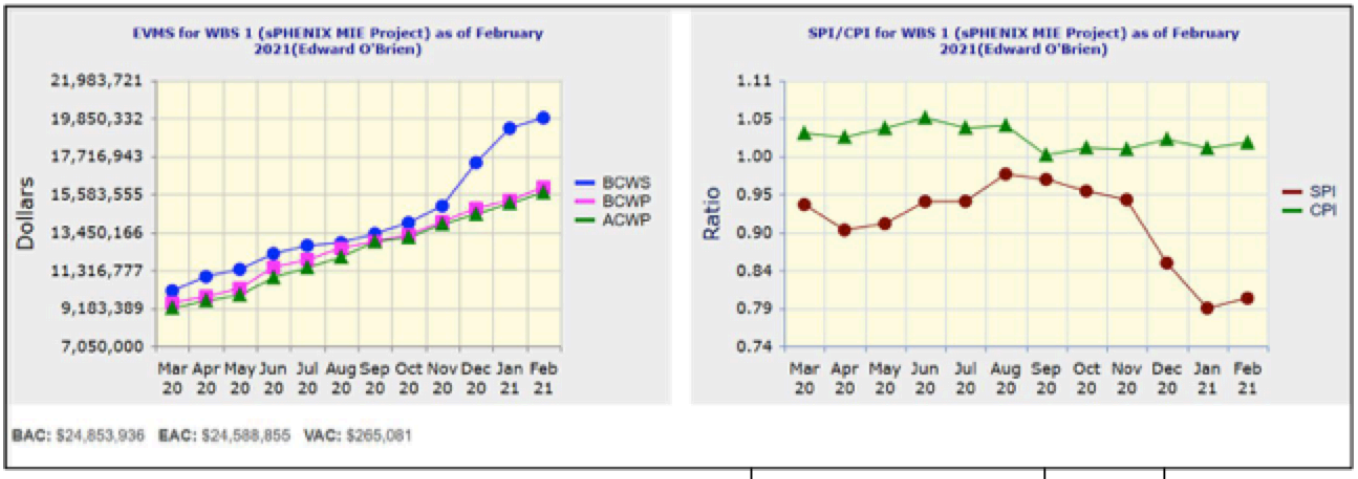
Work for Next 2-3 Months:

Columbia University colleagues will send everything needed to do the full chain test of the MBD at BNL: three MBD prototype D/S boards, the clock-fan out board, the clockmaster, and the crates. We have the DCM-2 and JSEB-2 here already, and we are working with the sPHENIX DAQ group to set that up for us. Columbia Univ will now proceed to work on the procurement of the production MBD electronics. BNL staff continues to meet weekly with grad students from Howard and Florida A&M Univ to train them on the MBD and the skill set required for testing and eventually for operating the MBD. The current plan is for them to come to BNL in the summer around the end of June, beginning of July, so that they can test the production electronics.

Issues:

None.

SPI and CPI Trends



Cumulative SPI	Cumulative CPI
0.80	1.02

Cumulative BCWS (Scheduled)	$19,852,872
Cumulative BCWP (Performed)	$15,954,504
Cumulative ACWP (Actual)	$15,658,993

DOE SPI or CPI Value Thresholds
- 0.90 to 1.15
- 0.85 to 0.89 or 1.16 to 1.25
- <0.85 or >1.25

February 2020 Cost Performance Report

8. PERFORMANCE DATA

CA (3)	CUMULATIVE TO DATE					AT COMPLETION				
	BUDGETED COST		ACTUAL	VARIANCE		BUDGETED	ESTIMATED	VARIANCE		
ITEM	WORK SCHEDULED	WORK PERFORMED	COST WORK PERFORMED	SCHEDULE	COST				SPI	CPI
(1)	(7)	(8)	(9)	(10)	(11)	(14)	(15)	(16)		
1.01A Project Management	1,833,395	1,833,395	1,720,817	0	112,577	1,951,679	1,839,101	112,577	1.00	1.07
1.02A TPC	4,245,257	2,909,622	2,684,498	-1,335,635	225,125	5,026,775	4,810,241	216,534	0.69	1.08
1.03A EMCal	5,199,555	4,764,530	5,005,024	-435,025	-240,495	6,070,008	6,313,317	-243,308	0.92	0.95
1.04A HCal	2,814,863	2,632,727	2,661,537	-182,137	-28,810	4,099,592	4,133,195	-33,603	0.94	0.99
1.05A Calorimeter Electronics	5,097,025	3,189,305	2,917,219	-1,907,720	272,087	6,290,621	6,026,762	263,859	0.63	1.09
1.06A DAQ & Trigger	492,607	525,778	590,575	33,171	-64,797	1,245,090	1,314,473	-69,382	1.07	0.89
1.07A MinBias Trigger Detecto	170,170	99,148	79,323	-71,022	19,825	170,170	151,766	18,404	0.58	1.25
b. COST OF MONEY	0	0	0	0	0	0	0	0		
c. GENERAL AND ADMINISTRATIV	0	0	0	0	0	0	0	0		
d. UNDISTRIBUTED BUDGET						0	0	0		
e. SUBTOTAL	19,852,872	15,954,504	15,658,993	-3,898,368	295,511	24,853,936	24,588,855	265,081	0.80	1.02
f. Contingency						2,146,064				
g. TOTAL	19,852,872	15,954,504	15,658,993	-3,898,368	295,511	27,000,000				
9. RECONCILIATION TO CONTRACT BUDGET BASELINE										
a. VARIANCE ADJUSTMENT				0	0					
b. TOTAL CONTRACT VARIANCE				-3,898,368	295,511	0	0	0		

CLASSIFICATION (When Filled In)

$8,929,862	ETC
$8,899,432	BCWR
24.03 %	% Contingency on ETC
24.11 %	% Contingency on Remaining Work
79.88 %	% Planned
64.19 %	% Complete
63.00 %	% Spent

DOE SPI or CPI Value Thresholds
- 0.90 to 1.15
- 0.85 to 0.89 or 1.16 to 1.25
- <0.85 or >1.25

*Highlights in table above takes variance $ into consideration, not just Indices

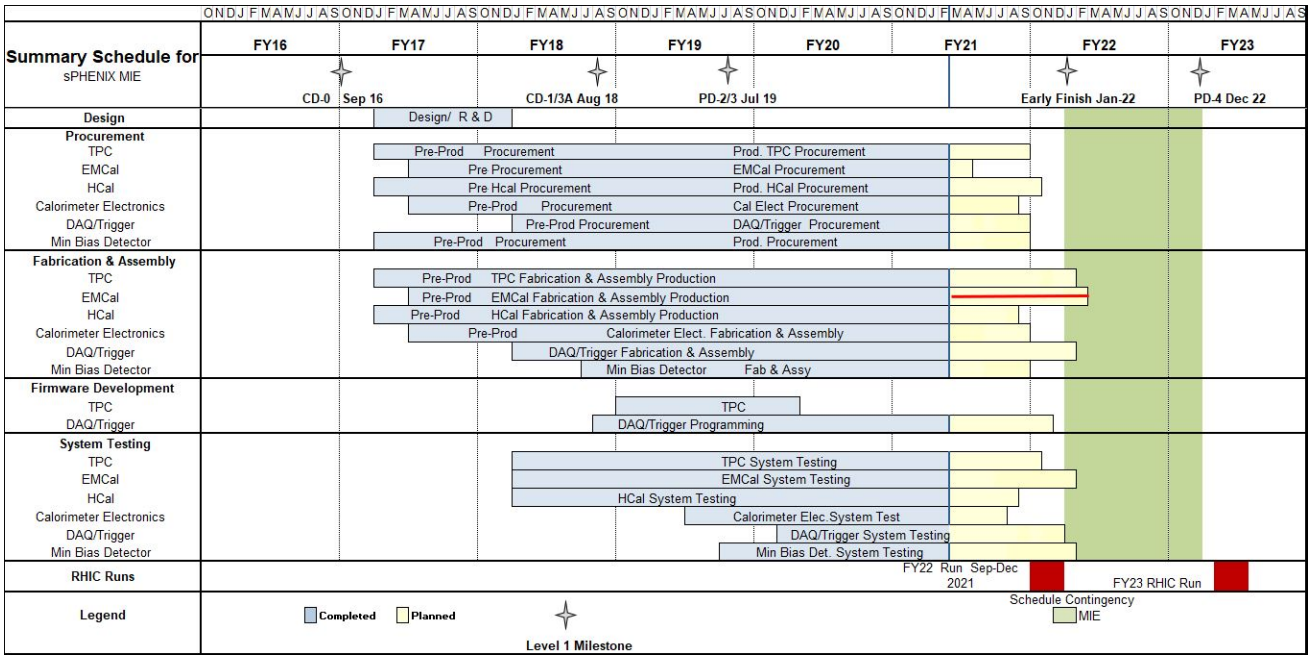
L1 & L2 Milestones

#	WBS	Milestone Name	Target Milestone Date	Forecast	Actual Finish	Variance (in work days)
1	01.01.2001	Approve Project Baseline and Construction PD2/3	30-Sep-19	20-Sep-19 A	20-Sep-19	6
2	01.02.02.02	Production Readiness Review - TPC Module Factories	31-Dec-19	17-Dec-19 A	17-Dec-19	8
3	01.03.02.03.02	EMCal Preproduction Sector 0 Assembled	31-Dec-19	25-Nov-19 A	25-Nov-19	23
4	01.02.06.02	Production Readiness Review - TPC DAM	28-Feb-20	04-Feb-20 A	4-Feb-20	16
5	01.05.02.03	HCal Preproduction FEE Complete	30-Apr-20	22-Jan-20 A	22-Jan-20	70
6	01.05.02.01	EMCal Electronics Preproduction Complete	29-May-20	28-May-20 A	28-May-20	0
7	01.03.01.03.01	EMCal W Powder Acquisition Complete	30-Jun-20	15-Jun-20 A	15-Jun-20	11
8	01.03.02.03.03	EMCal Production Readiness Review Blocks/Modules/Sectors Complete	31-Jul-20	30-Jul-20 A	30-Jul-20	1
9	01.02.05.03	SAMPA ASIC Performance Accepted	30-Sep-20	29-May-20 A	29-May-20	86
10	01.05.2001	EMCal/HCal SiPM Sensor Procurement Complete	30-Oct-20	28-Feb-20 A	28-Feb-20	171
11	01.05.02.04	HCal SiPM Boards Assembly Complete	30-Nov-20	22-Sep-20 A	22-Sep-20	45
12	01.06.02.03	Trigger L1 Preproduction complete	26-Feb-21	28-Jun-21		-86
13	01.05.02.02	EMCal SiPM Boards Production Complete	31-Mar-21	27-May-21		-42
14	01.04.04.02	First Outer HCAL Sector and Splice Plates Ready to Install	30-Apr-21	25-Feb-21 A	25-Feb-21	46
15	01.04.2001	Inner HCAL Support Structure Ready for Installation	30-Apr-21	9-Aug-21		-69
16	01.02.01.06	GEM Production Complete	31-May-21	15-Mar-21		54
17	01.03.01.03.01	EMCal Scintillating Fiber Acquisition Complete	31-May-21	25-Feb-21 A	25-Feb-21	67
18	01.02.06.03	TPC DAM Felix 2.0 Production Complete	28-Jun-21	31-Aug-21		-46
19	01.05.02.04	HCal Electronics Complete: Production	30-Jun-21	7-Apr-21		58
20	01.02.05.04	TPC FEE Production Complete	16-Aug-21	29-Oct-21		-53
21	01.05.02.02	EMCal Electronics Complete	16-Aug-21	28-Oct-21		-52
22	01.05.03.02	Calorimeter Electronics Complete	20-Sep-21	28-Oct-21		-28
23	1.07	MinBias Detector Ready to Install	30-Sep-21	14-Dec-21		-50
24	01.06.03.03	GL1 Ready to Operate	30-Sep-21	24-Jan-22		-76
25	01.01.2001	Early Project Completion	29-Oct-21	7-Feb-22		-65
26	01.02.01.08	TPC Ready to Install (Assembly Complete)	29-Oct-21	21-Jan-22		-55
27	01.02.06.03	TPC DAM Production Complete	29-Oct-21	12-Nov-21		-10
28	01.04.04.02	Last Outer HCAL Sector Ready to Install	29-Oct-21	31-Aug-21		40
29	01.06.01.03	DAQ Production: DAQ Ready for Operation	29-Oct-21	30-Dec-21		-41
30	01.06.02.04	LL1 Trigger Production Complete	29-Oct-21	25-Jan-22		-57
31	01.06.02.04	LL1 Ready to Operate	29-Oct-21	25-Jan-22		-57
32	01.03.02.03.03	EMCal Ready to Install	29-Nov-21	4-Feb-22		-47
33	01.01.2001	Approve Project Closeout PD-4	30-Dec-22	29-Dec-22*		0

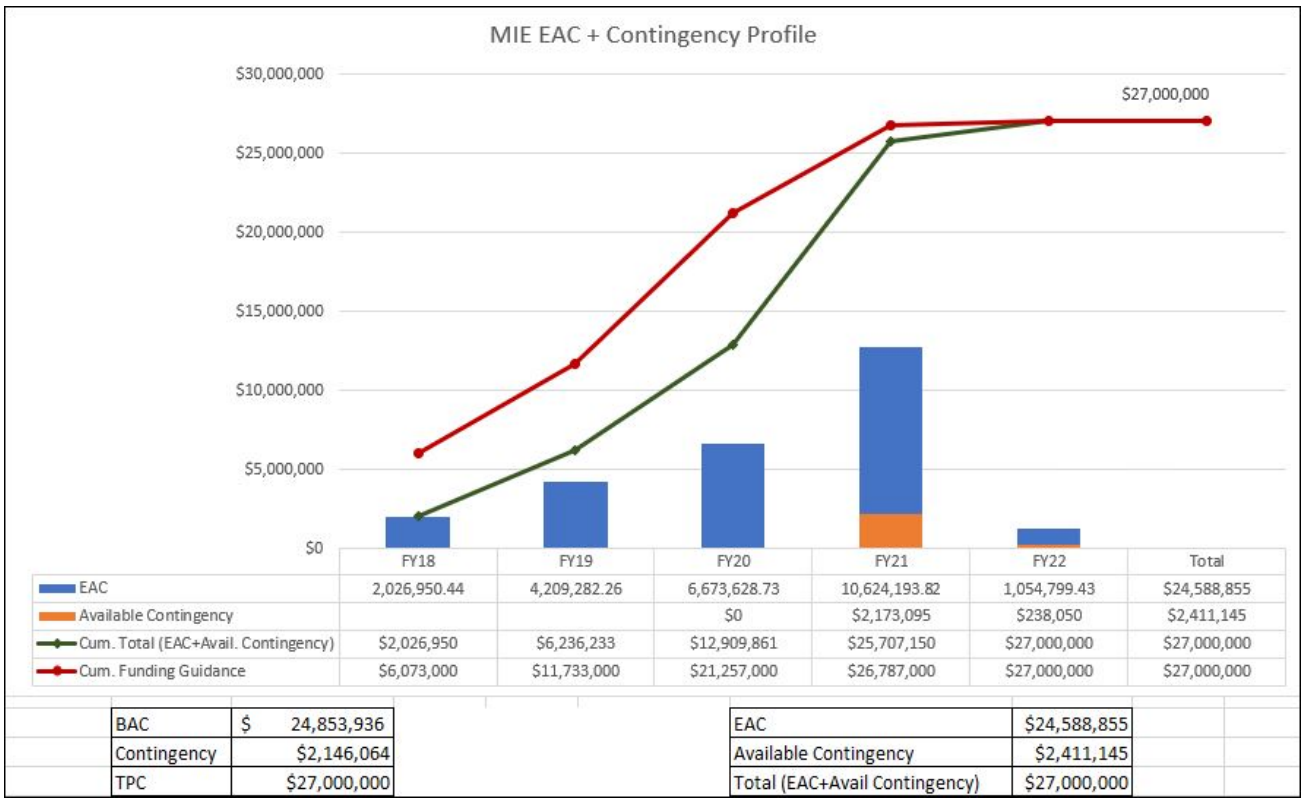
sPHENIX Budget Profile:

Funding Profile At Year k$								
	Prior Yrs	FY17	FY18	FY19	FY20	FY21	FY22	Total
R&D		1,513	4,260	350				**6,123**
CDR		100	200					**300**
PED								
Pre-ops								
OPC (R&D+CDR)		**1,613**	**4,460**	**350**				**6,423**
TEC				**5,310**	**9,524**	**5,530**	**213**	**20,577**
Total Project Cost		**1,613**	**4,460**	**5,660**	**9,524**	**5,530**	**213**	**27,000**

Summary Schedule with critical path



Estimate at Completion Profile



	FY18	FY19	FY20	FY21	FY22	Total
EAC	2,026,950.44	4,209,282.26	6,673,628.73	10,624,193.82	1,054,799.43	$24,588,855
Available Contingency			$0	$2,173,095	$238,050	$2,411,145
Cum. Total (EAC+Avail. Contingency)	$2,026,950	$6,236,233	$12,909,861	$25,707,150	$27,000,000	$27,000,000
Cum. Funding Guidance	$6,073,000	$11,733,000	$21,257,000	$26,787,000	$27,000,000	$27,000,000

BAC	$ 24,853,936
Contingency	$2,146,064
TPC	$27,000,000

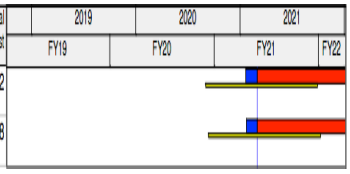
EAC	$24,588,855
Available Contingency	$2,411,145
Total (EAC+Avail Contingency)	$27,000,000

Baseline/Contingency Log

Baseline/Contingency Log - sPHENIX MIE Project							
Date	PCR ID	PCR Title	WBS affected	sPHENIX MIE Baseline Cost	PCR Change	Contingency	Total Project Cost
20.09.2019	Approved MIE	Setting up Baseline	all	$22,169,490		$4,830,510	$27,000,000
24.09.2019	007A	Hcal Scin Tiles placed Contract delivery schedule	1.04 HCal	$22,132,844	($36,646)	$4,867,156	$27,000,000
31.01.2020	008A	OHCal Sci.Tiles delivery schedule update	1.04 HCal	$22,132,943	$100	$4,867,056	$27,000,000
27.02.2020	009A	Extending the lead time for IHCal Support Rings	1.04 HCal	$22,132,943	$0	$4,867,056	$27,000,000
31.03.2020	011A	Added management labor for EMCal block production. EMCal Powder and TPC Sampa Cost and Delivery Schedule update	1.02 TPC and 1.03 EMCal	$22,193,813	$60,870	$4,806,187	$27,000,000
28.04.2020	013A	EMCal Block assembly contract details schedule update	1.03 EMCal	$22,195,549	$ 1,736	$4,804,451	$27,000,000
27.05.2020	014A	EMCal Light guides delivery schedule; EMCal SiPM daughterboards for Sectors 13-64 contract schedule	1.03 EMCal and 1.05 Cal E	$22,176,963	$ (18,586)	$4,823,037	$27,000,000
19.06.2020	105A	COVID-19 Schedule Adjustments	All	$22,198,743	$ 21,780	$4,801,257	$27,000,000
30.10.2020	017A	Risk Reduction and Realization	1.2; 1.3; 1.4; 1.5	$24,309,836	$ 2,111,093.00	$2,690,164	$27,000,000
31.12.2020	019A	Additional tech labor for EMCal and HCal	1.3; 1.4	$ 24,531,362	$ 221,527	$ 2,468,638	$ 27,000,000
31.01.2021	020A	Move out the Early Project Completion milestone; add tech labor	1.1; 1.2; 1.3; 1.4	$ 24,897,760	$ 366,398	$ 2,102,240	$ 27,000,000
28.02.2021	021A	IHCal Support Rings Placed Contract	01.04.2001	$ 24,853,936.00	$ (43,824.00)	$ 2,146,064.00	$ 27,000,000

Critical Path

Activity ID	Activity Name	At Completion Duration	Total Float	Start	Finish	BL Project Start	BL Project Finish	Variance - BL Project Finish Date	Budgeted Labor Units	Budgeted Nonlabor Units	Budgeted Total Cost	BL Project Total Cost
S187700	Install light guides on final blocks M&S	257	0	21-Jan-21 A	31-Jan-22	02-Sep-20	30-Sep-21	-80	0	1650	1,926	1,912
S188100	Install SiPMs daughterboards on final blocks M&S	259	0	22-Jan-21 A	03-Feb-22	11-Sep-20	08-Oct-21	-77	0	300	350	348



Variance Analysis

Reporting Period: 2/1/2021 - 2/28/2021

sPHENIX MIE Project (Edward O'Brien [18368])

	BCWS	BCWP	ACWP	SV in $	SV in %	CV in $	CV %	SPI	CPI
Current:	583,799	733,976	601,918	150,177	26%	132,058	18%	1.26	1.22
Cumulative:	19,852,872	15,954,504	15,658,993	-3,898,368	-20%	295,511	2%	0.80	1.02

	BAC
At Complete:	24,853,936

Threshold(s) Exceeded: Cumulative Schedule

Explanation of Variance/Description of Problem:

WBS 1.2.1 **TPC Mechanics:** One activity, S120100 Production of GEM foils, has an SV of -$64,025, due to late delivery of GEM foils manufactured at CERN. The delay is due to a COVID-related shutdown of the CERN factory and a subsequent four-month delay in GEM foil manufacture. WBS 1.2.2 **TPC GEM Modules R1**: One activity S125100 TPC R1 padplanes is not complete, with an SV of -$50,113. This in turn delays two successor activities, S125500 TPC R1 modules build, with SV = -$32,820 and S125600 TPC R1 Modules test, with SV = -$27,806. The total SV resulting is -$110,739. The layout of the R1 padplane, the smallest of the three types, was hampered by signal trace routing issues which did not conform to design rules required by the printed-circuit board manufacturer. WBS 1.2.5 **TPC Front End Electronics**: There are five activities with significant SV. They are: activity S136500 TPC FEE Cooling System, SV = -$69,821, activity S141500 TPC FEE Production components (optical transceivers), SV =-$34,429, activity S141800 TPC FEE Production Components, SV = -$61,910, activity S142500 TPC FEE Low Voltage Power system, SV = -$205,153, and activity S143250, TPC FEE components, SV = -$42,033. The net SV is -$413,346. WBS 1.2.6 **TPC Data Aggregator Modules**: Three activities contribute to the SV: activity S147300 FELIX 2.0 production board, SV = $30,262, activity S147370 FELIX 2.0 board optical components, SV =-$93,719, and activity S138400 EBDC computers and peripherals, SV =-$244,769. WBS 1.2.7 **TPC Support Systems:** There are three areas of effort. The TPC Lasers delivery has started but only the first articles have been delivered, SV =-$202,339. The TPC Gas System has procured and received 25% of the components but still needs to place requisitions for the balance, SV =-$97,008. The TPC Cooling system has not procured the high value elements including the chiller/re-circulator, SV =-$73,653. The total SV for these key items is -$372,999. WBS 1.3.1 **EMCal Blocks:** There are four main items causing the SV. The S171800 Epoxy is only 48% complete, SV =-$23,148. Molds S172500 and fiber assemblies S172800 are behind schedule, SV =-$26,808. The S174000-S175500 Blocks for Sectors 26-41 are not complete, SV =-$82,280, nor is their shipping to BNL, SV =-$27,849. The total SV for these items is -$160,085. WBS 1.3.2 **EMCal Modules and Sectors**: The S187400 Production Light Guide contract is only 40% complete, SV = -$144,077. The S195400 Mechanical parts for Final Sectors are only 75% complete, SV = $72,937. The S196100 Cooling System for Final Sectors was only 25% complete, SV = -$61,713. The total of these SVs is -$278,727. WBS 1.4.2 **Outer HCal Mechanics:** The S205100 Splice Plates are only 21% delivered, SV = -$239,626. WBS 1.4.4 **Outer HCal Sector Assembly and Testing**: The S209800 – S210200 assembly and testing of the production Outer HCal Sectors was nearly 2/3 complete and ahead of schedule, SV = $57,490. WBS 1.5.2 **Calorimeter Front End Electronics**: Seven separate activities contribute substantially to this SV. They are: activity S227605 EMCal SiPM daughter boards part 2, SV = -$18,565, activity S229300 EMCal preamplifiers only 6% delivered, SV = -$516,664, activity S231800 EMCal internal cables are only 65% complete, SV = -$100,868, activity S233250 EMCal trunk signal cables are not complete, SV = -$277,801, activity S234100 EMCal LV power system sectors 13-64 only 20% complete, SV =-$31,416, activity S244400 HCal External cables are only 30% complete, SV = -$71,358, and activity S244450 HCal trunk signal cables not complete, SV =-$53,325. The total SV for these activities is -$1,069,997. WBS 1.5.3 **Calorimeter Digitizers**: There are two activities contributing to this SV. One is S252700 Digitizer Parts, SV = -$678,538 and the other is S252800 Digitizer Boards, SV = - $149,785. WBS 1.6.1 **Data Acquisition**: Three activities have been completed ahead of schedule, resulting in a positive SV = $203,950. These activities are S257600 Sub-Event-Buffer board production, SV = $47,634, S258400 Assembly and Trigger

Processor board production, SV = $113,823, and finally S259500 Buffer Box procurement, SV = $41,513. WBS 1.6.2 **Local Level-1 Trigger:** Activity, S263600 Preproduction Local Level-1 trigger, is not complete, resulting in SV = -$69,641. WBS 1.6.3 **Global Level-1 Trigger:** Activity S267600 Production of final GL1 is not complete, SV =-$32,673. WBS 1.6.4 **Timing System:** Activity S270300 Production of Timing System is not complete, SV =-$48,284. WBS 1.7 **Min Bias Trigger Detector**: Activity S273500 Min/Bias production digitizers is not complete, SV = -$17,143, and activity S273600 MBD Shaper/Disc Board is not complete, SV = -$53,879, for a total of -$71,022.

Impact:
WBS 1.2.1 **TPC Mechanics**: None as yet. All delivered GEM foils, some 58% to date, have been mounted on frames and prepared for assembly into readout modules for the TPC. WBS 1.2.2 **TPC GEM Modules R1**: None as yet. The rest of R1 module construction is proceeding. Pad planes are to be attached to the modules as a late step in the module assembly sequence. Positive float remains. WBS 1.2.5 **TPC Front End Electronics**: None as yet. WBS 1.2.6 **TPC Data Aggregator Modules**: None WBS 1.2.7 **TPC Support Systems**: These are all items being procured well ahead of their needed installation in order to allow for more time to test them on the bench and adjust settings. WBS 1.3.1 **EMCal Blocks**: None WBS 1.3.2 **EMCal Modules and Sectors**: None WBS 1.4.2 **Outer HCal Mechanics**: None, the initial delivery is complete, ahead of the milestone for the Outer HCal. WBS 1.4.4 **Outer HCal Sector Assembly and Testing**: None WBS 1.5.2 **Calorimeter Front End Electronics**: none except for the EMCal preamps, which will be needed by the EMCal sector production line starting in early March. WBS 1.5.3 **Calorimeter Digitizers**: None presently. The EMCal and OHCal sector production lines have an adequate number of digitizers to perform all needed QA during remaining detector construction. Therefore, the remaining digitizers are only needed by the completion of the MIE project. WBS 1.6.1 **Data Acquisition**: None WBS 1.6.2 **Local Level-1 Trigger:** None WBS 1.6.3 **Global Level-1 Trigger**: None WBS 1.6.4 **Timing System**: None WBS 1.7 **Min Bias Trigger Detector:** None

Corrective Action:
WBS 1.2.1 **TPC Mechanics**: The order remains in progress. We are supporting a full-time technician at CERN to speed manufacture of remaining foils. The revised delivery schedule provided by CERN will meet our assembly schedule for the TPC readout modules. WBS 1.2.2 **TPC GEM Modules R1**: The signal trace routing issue has been resolved, the routing of the board is complete, and the contract for the manufacture of the pad-plane circuit cards has been placed with the same vendor who successfully built all the pad-plane circuit cards for R2 and R3 modules. The vendor has quoted a delivery time compatible with the schedule for R1 module assembly. WBS 1.2.5 **TPC Front End Electronics:** All the items covered by these activities are being ordered, with one exception, the optical transceivers, which were tested in February for operation in magnetic field. The manufacturer announced in February that it is replacing this part with a newer and less expensive version; the new variant will have to be the one purchased by sPHENIX and thus also will need to be tested in magnetic field, although no issues are expected based on technical input from the manufacturer. The required design and procurement reviews are complete. The cooling system requires a series of machined parts, for which the procurement is placed, and manufacturing is started. The TPC FEE production components are on order. The TPC FEE Low Voltage power supplies are under contract with the vendor scheduling all deliveries over the next two months. The TPC FEE components, mostly the quad transceivers, will be ordered later in the spring because they are added to the assembled boards by hand after the automatic board assembly is complete. WBS 1.2.6 **TPC Data**

Aggregator Modules: The EBDC computer prototype passed all tests. The production order has now been submitted to Procurement and is out for bid. The FELIX production board order is submitted; the components are in hand and thus the activity is 80% complete, and only board preparation and assembly remains. The FELIX optical components are fiber optics and specialized connectors to group and route signals from the TPC FEE cards (WBS 1.2.5) to the FELIX boards. The topology of these connectors must accommodate a board used to reprogram the FEE cards in case of radiation-induced single event upsets (SEUs); the architecture of this board was determined at the beginning of March. This fiber topology thus needs an update, meaning the bill of materials for the fiber optic components must be revised. This revision will be completed in March. WBS 1.2.7 **TPC Support Systems**: The Preliminary Design reviews are complete and all three of these subsystems have moved to acquiring first articles. Proper operation is to be demonstrated prior to holding the Final Design reviews and the Procurement Readiness reviews, which are planned for March. WBS 1.3.1 **EMCal Blocks**: The Epoxy must be bought within a few weeks of use, due to shelf-life issues. It is a commodity item and is purchased on an as-needed basis. The delayed Blocks were caused by personnel absences due to the COVID-19 pandemic. Block production resumed over the summer of 2020 and returned to planned production rates in the Fall. This particular SV will persist until about 2 weeks before the Project is complete, at which time Block production will be complete. The Early Completion date for the MIE project was adjusted in January 2021 to reflect this. WBS 1.3.2 **EMCal Modules and Sectors:** The light guide production was suspended at the vendor until QA and tooling-fixture issues were examined and resolved. These issues were addressed over October-December and production deliveries have resumed at the planned rate and ahead of when they are needed to produce sectors. The light guide vendor has qualified more machine shops supplying him to further improve his delivery rate in the future. The mechanical parts are being delivered somewhat ahead of schedule, with all but the sawteeth/strongback in fact being complete; the saw teeth delivery schedule is about a month ahead of need-by date. The cooling system components are being manufactured by a local small company at a pace about 2 months ahead of need-by date. WBS 1.4.2 **Outer HCal Mechanics**: Continued contact with the vendor. The vendor had to reject some of the initial parts due to an issue of cracks developing in the steel after heat-treating and subsequent machining. The technique for heat-treating was changed, a different method of machining the precision holes was selected and employed, and the problem has not recurred. Delivery of first parts occurred in February and delivery of the balance of the contract occurred the first week of March. WBS 1.4.4 **Outer HCal Sector Assembly and Testing:** None needed, work is ahead of schedule. WBS 1.5.2 **Calorimeter Front End Electronics**: The contract is placed for the EMCal preamplifiers. The vendor has now delivered a first batch, adequate to instrument more than 3 sectors. The vendor has now obtained all the long-lead-time parts for the main EMCal preamplifier production and will start mass production in March. The vendor for the EMCal internal cables has been delivering them regularly on a schedule well in advance of the need for them during EMCal sector construction. The Procurement readiness review was held in January for the external/trunk cable orders, EMCal and HCal, and procurement documents are being prepared. Potential vendors indicate they can meet the requested delivery schedule for these cables. WBS 1.5.3 **Calorimeter Digitizers:** The contract for the production digitizers is placed. The vendor indicates they are placing orders for production quantities of all parts but that world-wide supply chains have led to more lead time than foreseen pre-COVID. We continue to monitor the progress by this vendor. WBS 1.6.1 **Data Acquisition:** None, activities were completed early. WBS 1.6.2 **Local Level-1 Trigger**: The prototype Local Level-1 trigger board has been under full-speed testing for several months. Results to date indicate it will meet all requirements, completing the above activity. A review held in late February determined that a few small revisions

to the board are needed. These revisions are proceeding. The production manufacture is still expected during 2021 based on the existing board assembly house and Bill of Materials. That production will complete this level-3 WBS. WBS 1.6.3 **Global Level-1 Trigger:** The prototype Global Level-1 Trigger is being used as part of an extended test of electronics for sPHENIX. This test requires multiple front-end cards to operate, respond to triggers and timing signals, and send data to the production DAQ computers correctly over an extended period. This test is planned to last until early March. Assuming a positive outcome, the production Global Level-1 Trigger will be assembled using the existing blueprints. WBS 1.6.4 **Timing System**: The prototype Timing System is being used as part of an extended test of electronics for sPHENIX. This test requires multiple front-end cards to operate, respond to triggers and timing signals, and send data to the production DAQ computers correctly over an extended period. This test is planned to last until early March. Assuming a positive outcome, the production Timing System will be assembled using the existing blueprints. WBS 1.7 **Min Bias Trigger Detector**: The digitizers needed for the MBD are part of the larger digitizers order noted above for WBS 1.5.3 A final design review and production readiness review were held for the MBD shaper/discriminator board in February, no required changes were identified, and the board approved for production procurement. This procurement is being placed with the vendor who prepared and tested the prototype versions. Completion by December 2021 is anticipated.